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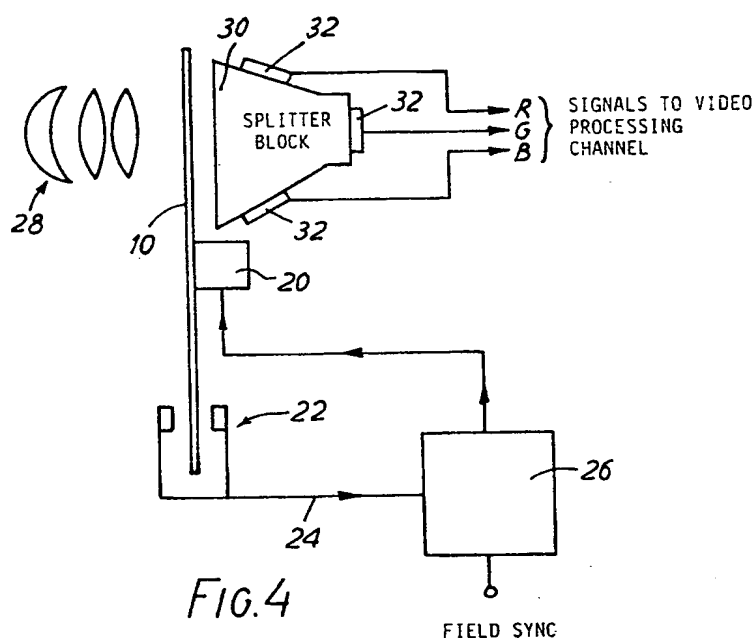
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(54) Video cameras

(57) An improvement for a video camera comprises means 10 for restricting the effective exposure of photo-sensitive elements 32 of the camera to scene light, in order to substantially eliminate flicker arising from differences between a camera field rate and the rate of illumination variation due to mains frequency. The exposure is related to the period of illumination variation during each field.

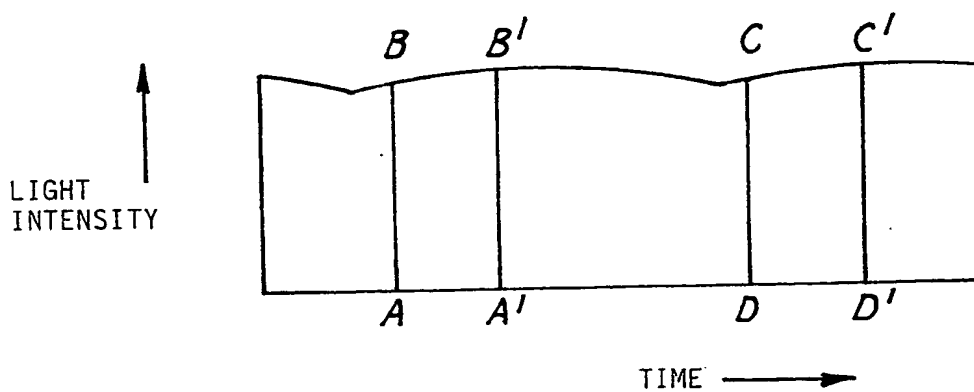
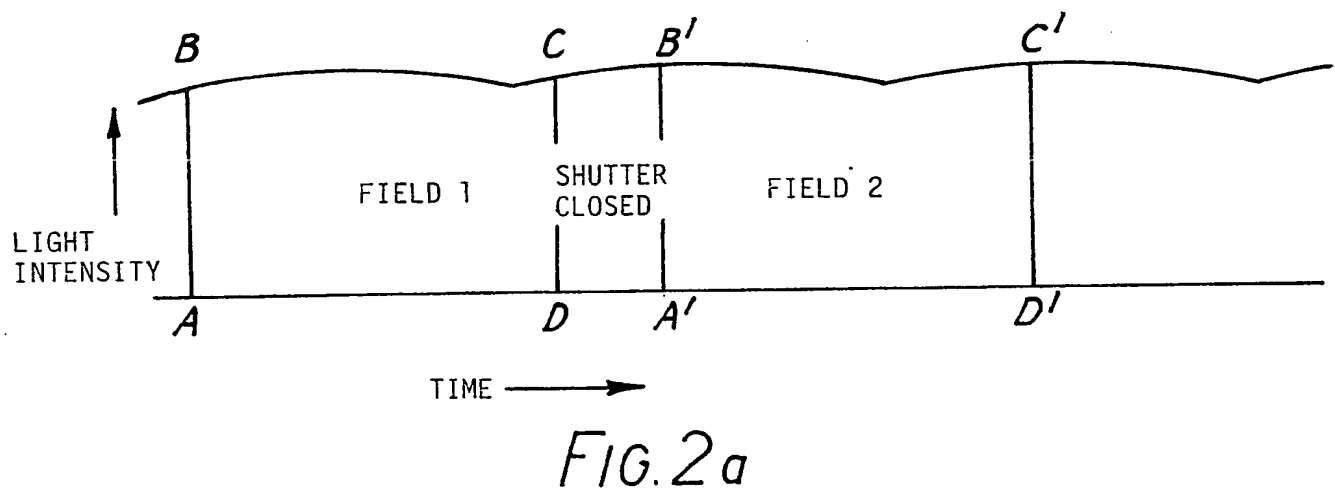
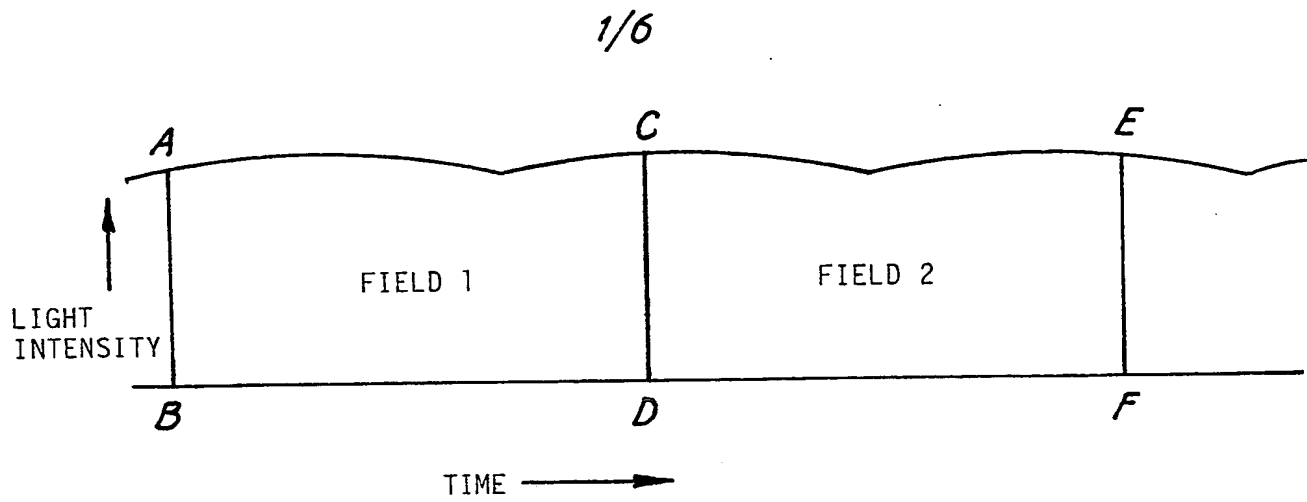
In one embodiment the restricting means consist of a rotating shutter 10 located between a camera lens 28 and the photo-sensitive elements 32 of the camera. In another embodiment the restricting means consist of an electronic signal blocking device.

The improvement has applications on both tube and charge-coupled-device cameras.



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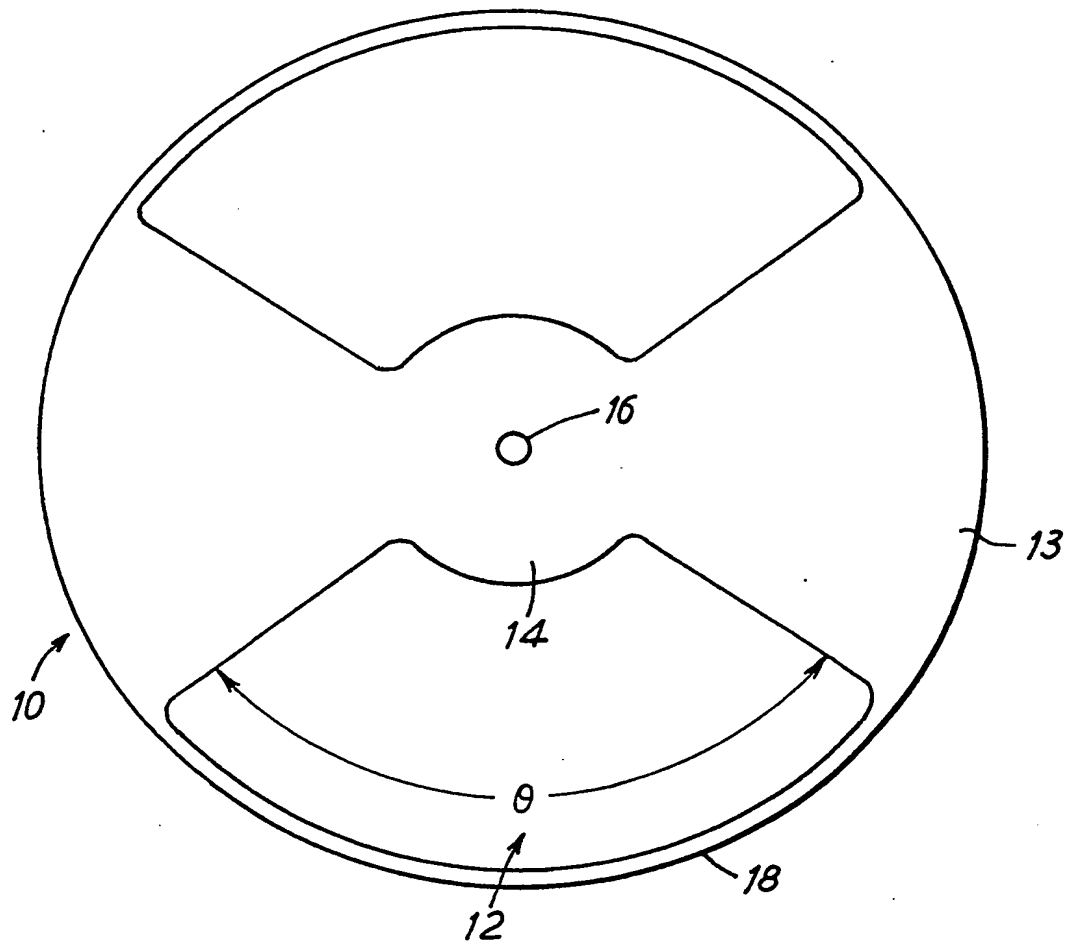
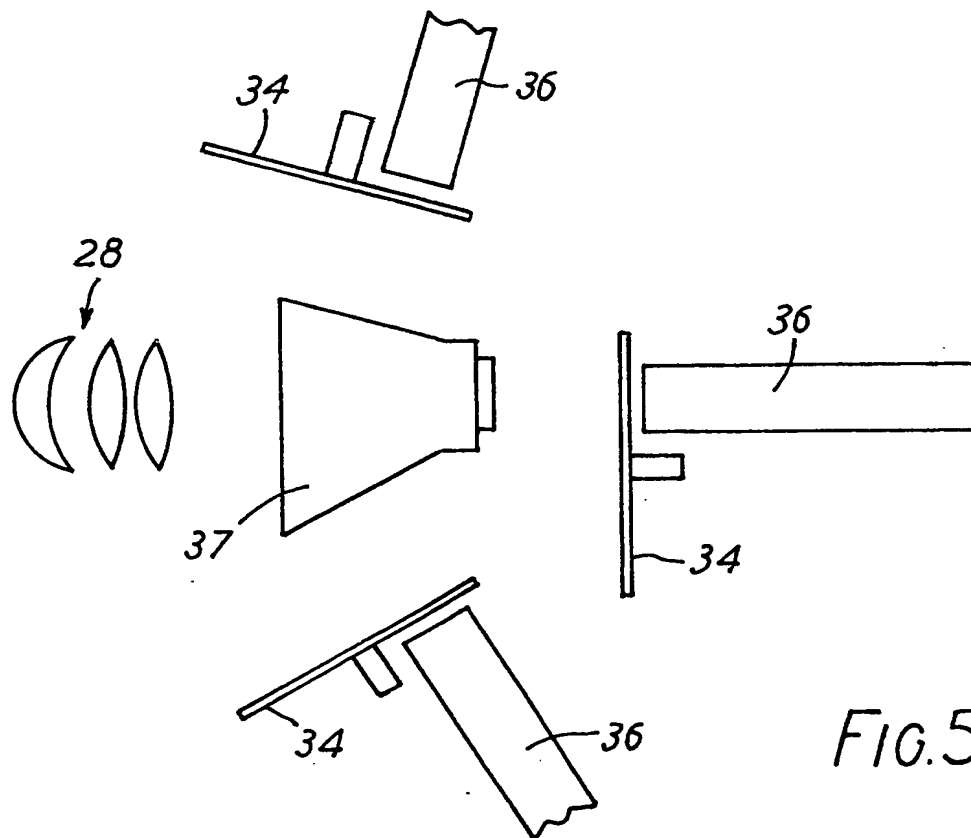
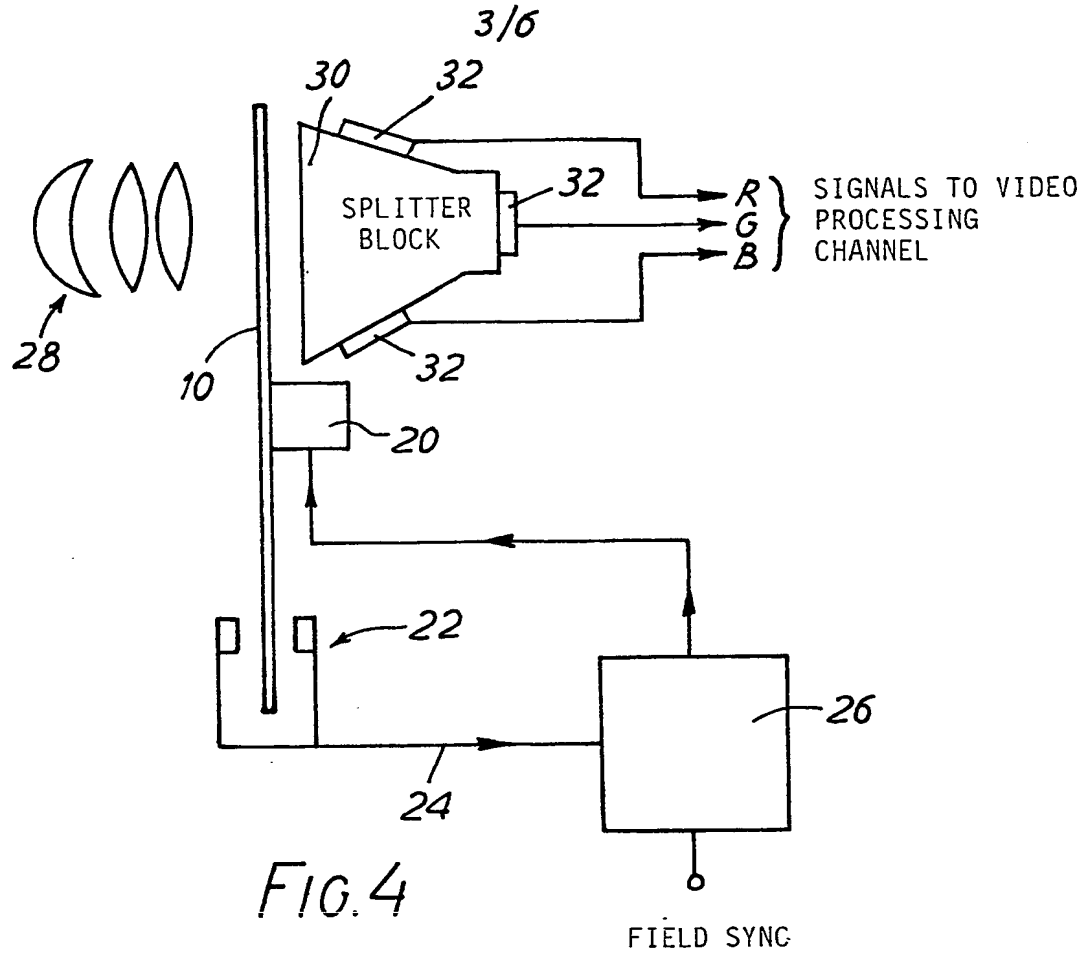


FIG. 3



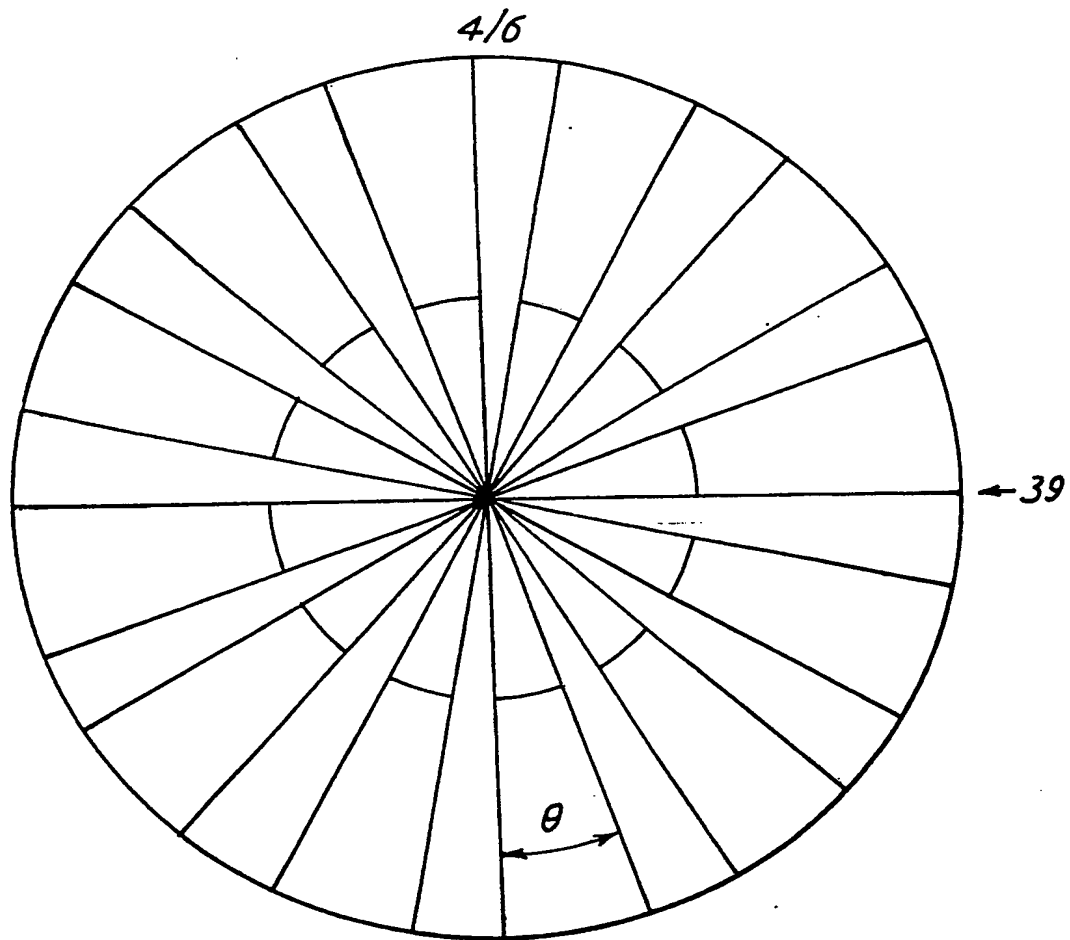


FIG. 6

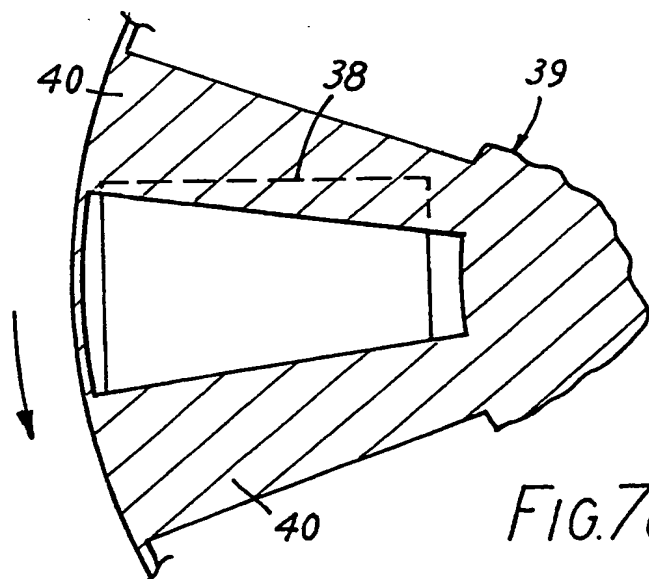


FIG. 7a

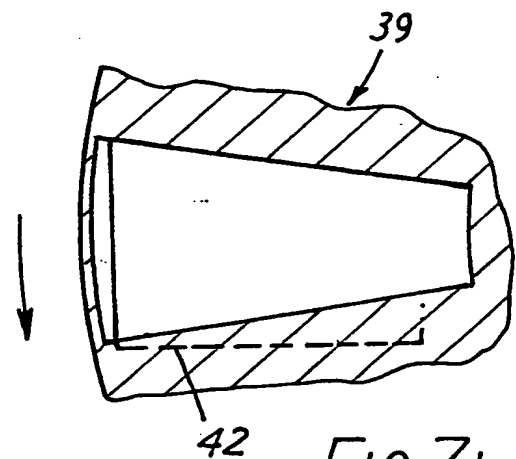
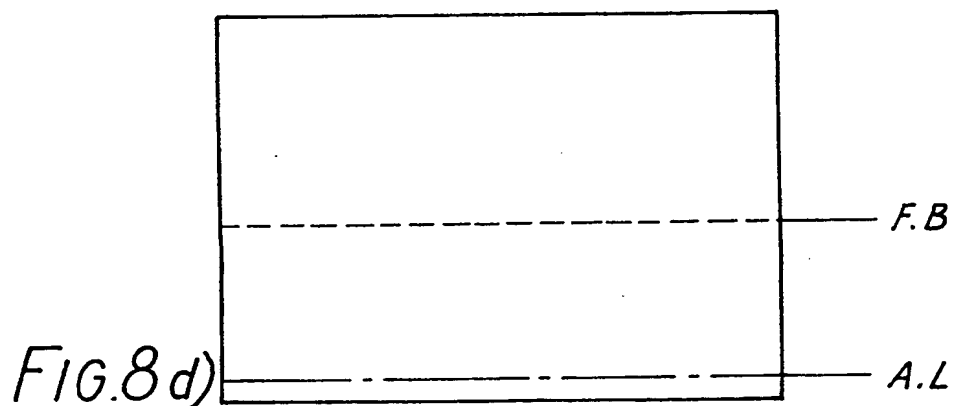
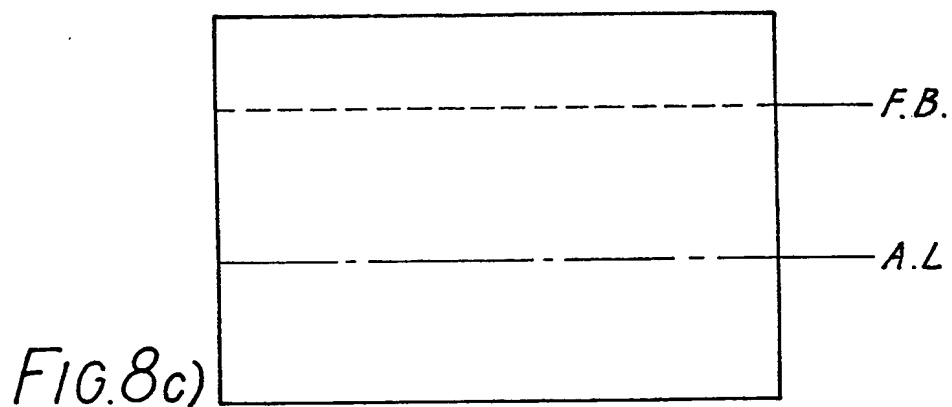
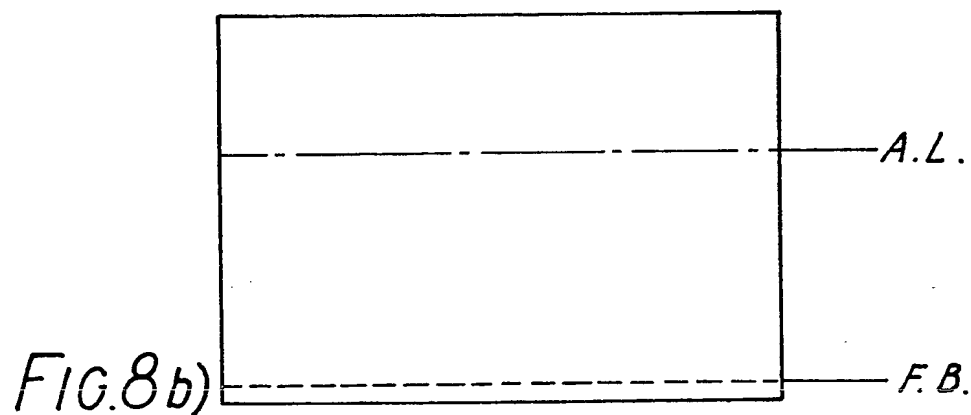
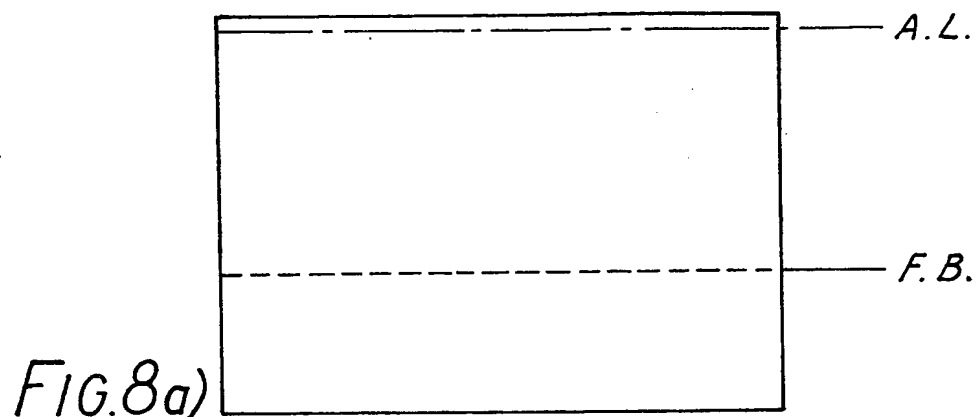


FIG. 7b

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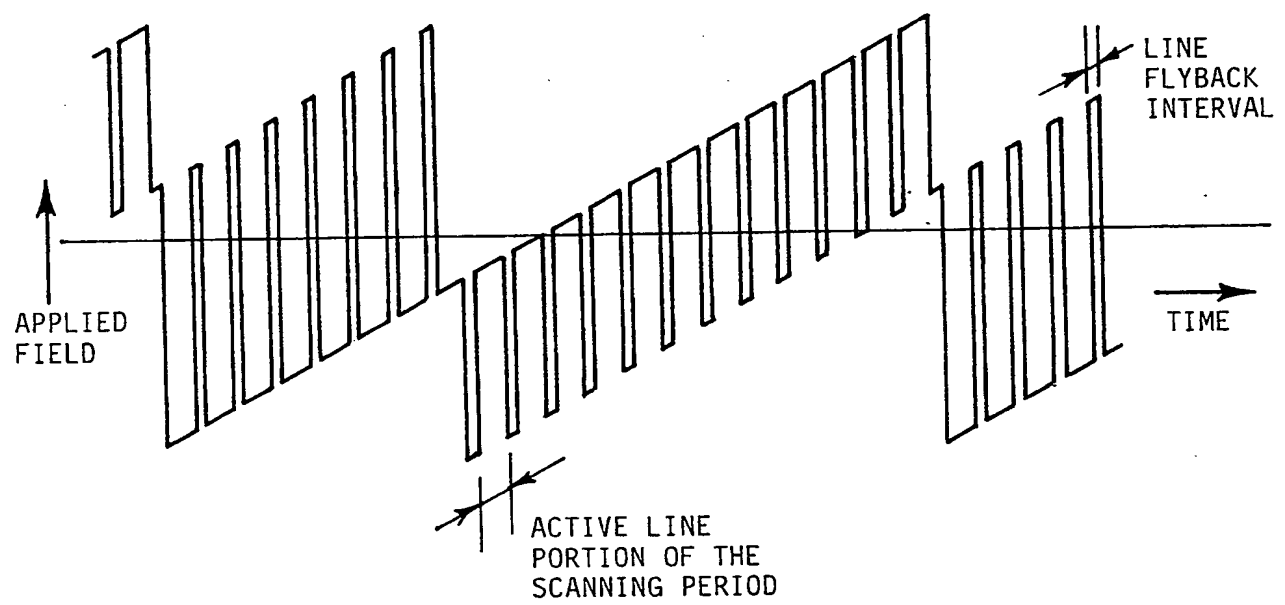


FIG. 9

SPECIFICATION

Improvements relating to video cameras

This invention relates to video cameras and more particularly to eliminating flicker in high definition television cameras induced by ambient illumination variations.

One of the problems encountered in the development of high definition television (HDTV) standards is that camera field frequencies that are substantially different from the local mains supply frequency give rise to an objectionable level of flicker at the beat frequency between the HDTV field frequency and twice the mains frequency. This arises because the level of light emitted by these lamps fluctuates with time as the applied voltage varies through the cycle. Because the light output depends on the modulus of the applied voltage and is independent of polarity, the frequency of the illumination fluctuation is twice that of the mains frequency.

The camera integrates this ambient illumination of an image in each field period, causing the flicker. Figure 1 of the drawings illustrates how the total light integrated in this way over a field varies as the field frequency beats with the frequency of the illumination variation. The area bounded by points ABCD is different to the area bounded by CDEF, hence the variation.

Solutions that have been suggested include the use of multiple mains phases to power several lamps, ensuring that the mean level of scene illumination remains constant, and the use of variable electrical gain, linked to the calculated level of illumination flicker, to compensate the output of the camera. Neither of these is very successful. In the first case, it is difficult to balance the illumination for all parts of the scene, including shadows. In the second case, mixed illumination conditions (daylight mixed with the arc illumination for example) can give rise to severe problems, again varying between shadowed and highlighted areas.

In the recent RCA charge coupled device camera, the CCD-1, as described by G. W. Hughes in the 'RCA Engineer' of Nov/Dec 1984, a shutter has been used to overcome vertical highlight streaking caused by the frame transfer sensor. Such shutters have also been suggested as a method for improving the temporal resolution of television cameras (the sharpness of moving objects).

We have appreciated that a shutter can be used in or in association with a camera in such a way as to eliminate or at least substantially reduce flicker caused by ambient illumination variations. The shutter is held open for a duration related to the period of the mains frequency, and its frequency of opening is locked to the camera field frequency.

According to the present invention there is provided a video camera comprising optical-to-electronic transducer means for viewing an illuminated scene and producing an electrical signal representative of the scene in scanned form having a defined scan rate, and means for restricting the effective exposure time of the transducer means such that the exposure time is related to the period

of the frequency of the variation in ambient scene light during each scan of the transducer.

Some embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a graph illustrating typical cyclical variations in ambient artificial light intensity;

Figures 2a and 2b are graphs illustrating the concept behind the present invention;

Figure 3 is a shutter for use in one embodiment of the present invention;

Figure 4 is a schematic diagram of an embodiment of the present invention applied to a CCD camera;

Figure 5 is a schematic diagram of a further embodiment of the invention applied to a tube camera;

Figure 6 is an alternative shutter for use in the present invention;

Figures 7a and 7b illustrate a shuttering operation according to the present invention applied to a tube camera;

Figures 8a, 8b, 8c and 8d illustrate electronic shuttering according to the invention applied to a tube camera; and

Figure 9 illustrates a field deflection waveform for a tube camera having the electronic shuttering of Figures 8a to d.

As mentioned above, Figure 1 shows how the total light integrated over each field bounded by A B C D varies as the field frequency beats with the frequency of the varying ambient illumination intensity. This results in the observed flicker.

If the time for which the shutter is open matches one cycle of the illumination fluctuation (1/100th second in 50Hz mains countries, or 1/120th second for a 60Hz mains frequency), then the amount of light collected per field is constant. This is illustrated in Figure 2a; the light collected during the field is again marked by the area ABCD. The area A'B'C'D' illustrates the light collected in a following field. Figure 2b shows these two areas redrawn so that they intercept the same cycle of the illumination fluctuation. Clearly the areas ABB'A' and DCC'D' are equal therefore the areas ABCD and A'B'C'D' are also equal.

The operation of a synchronised shutter to eliminate flicker will be different depending on whether a conventional camera tube or a charge coupled device (CCD) area sensor is used as the pickup device in the camera. If a frame-transfer CCD is used, the integrated charges from all parts of the image detection area are moved together into the readout area during the frame transfer interval.

Thus the times marking the start and end of each integration interval are coincident for all parts of the image sensing area. In consequence the shutter is made to cut off the incident light from all parts of the image sensing area before the frame transfer period and ensure that the light is cut off until this period has ended.

The shutter in Figure 3 comprises a thin disc 10 of blackened metal having equal angularly spaced holes 12 to define blades 13 of the remaining metal. The holes 12 are cut axially about a central core 14

of the disc 10 which supports the disc on a shaft 16 of a motor (not shown). In this embodiment the disc 10 is provided with an integral circumferential rim 18 which adds to the rigidity of the blades 13.

5 The motor 20, illustrated schematically in Figure 4, is controlled in order to synchronise the opening period of the shutter to the field scan. A detector 22, which may be of the optical or proximity type, detects the rotation of the shutter.

10 An output from the detector 22 on line 24 supplies information on the rotation of the shutter to a servo circuit 26 which is also fed with field synchronising information, in order to control the motor speed and synchronisation.

15 The shutter rotates between a camera lens 28 and a camera prism splitter block 30 upon which charge coupled devices 32 relating to red, green and blue colour signals are mounted. The colour information from the CCD's 32 is then fed to video processing means (not shown).

Assuming a 60Hz field frequency, the speed of the motor 20 will be 1800 rev./min for the twin bladed shutter of Figure 3. If the time for which the shutter is open is fixed at 1/100th of a second in order to control the flicker caused by 50Hz mains, the sector angle θ in the disc of Figure 3 will be 108 degrees.

Because the shutter is rotated in front of the prism splitter block it is out of focus with respect to the CCD sensors 32. This means that the light is not abruptly cut off but instead fades to black and then fades up again. The flicker elimination is not affected, but it is necessary to ensure that the frame transfer of charge in the CCD sensor 32 occurs during the black period and that sufficient slack has been allowed to cope with tolerance errors in the shutter phase control, including tolerances in the servo 26. The larger the diameter of the shutter disc 10 the more margin there is for these tolerance errors but the more energy it requires to rotate it.

40 Consequently, there is a compromise to be reached between these two considerations.

In a camera using conventional tubes, the integrated charge is read off as the electron beam scans each part of the target. Thus the start and end of each integrated period varies from the top to the bottom of the image area. In this case the shutter is made to pass across the face of the camera tube in synchronisation with the scanning electron beam inside the tube.

50 With reference to Figure 5, an equivalent system for use on a tube camera comprises a separate shutter 34 corresponding to each primary colour camera tube 36. Scene information passes through a lens 28 and is, again, split into its primary colours by a splitter block 37 for reception by corresponding tubes 36. Again, motors driving the shutters are used but their depiction and that of the synchronising circuitry, which is similar to that in Figure 3, has been omitted for the sake of clarity.

60 Irrespective of what type of camera sensor is used, the object is the same; namely to restrict the exposure period of the camera to a part only of the field period. In each case the shutter frequency and phase is locked to the frequency and phase of the camera field scan.

The use of such a shutter will theoretically provide a total cure, therefore, for any illumination flicker. A more sophisticated analysis shows that, even if the shutter takes some time to open and close, the flicker is still suppressed provided only that the temporal characteristics of the opening and closing periods match.

In tube cameras the biggest problem is set by the need to ensure that the scanning electron beam is always covered by the shutters 34 as it sweeps down the tube-face (actually, because the camera lens inverts the image, the beam scans from bottom to top but it is easier to visualise the system without this additional complication). Consequently the shutters 34 must be more nearly in focus on the tube-face; this means that either a more complicated lens system should be used with one shutter in front of the splitter block 37, or else one shutter disc used per tube, as described. The optical design is made easier if the number of shutter blades is increased and the rotation speed reduced; Figure 6 shows one possible design of a shutter disc 39, based on a rotation speed of 300 rev./min. rather than 1800 rev./min. In this case the sector on the angle θ is reduced to 18 degrees.

Figures 7a and 7b show the position of the shutter of Figure 6 in relation to the camera tube electron beam at the start and finish of a field interval respectively. At the start of a field scan the broken line 38 indicates the line being scanned as obscured by the shutter. During the field period the shutter rotates anticlockwise, as depicted by the arrow, to bring the next available aperture between blades 40 into line with the scanned area as the line 42 is being scanned.

Although the shutters described thus far are mechanical it is, of course, quite possible to use an electronic shutter in the form of a signal blocking device behind the CCD image sensor in a camera. Such a shutter is described in "Electronic Control Of Integration Time In CCD Frame Transfer Image Sensors", by R. T. Bell and C. J. Morcom, published in IEE Conference Publication No. 253, Proceedings on the Conference on Photoelectric Imaging. This paper describes the use of particular driving waveforms to achieve electronic shuttering. These can be applied to flicker elimination although smearing of highlights on frame transfer may still occur.

Referring to Figures 8a, b, c and d, in tube cameras the electronic shuttering could be achieved by placing the shuttering means conceptually behind each tube sensor and vertically shifting the scanning electron beam during line flyback so that it discharges the signal in areas of the tube face that a mechanical shutter might normally cover. The normal scanning action (A.L.) of the electron beam during the active line period is unaffected. Figures 8a to d illustrate the position of the normal and flyback scans (A.L. and F.B. respectively) at several stages during the television field period. In Figure 8a, the normal line scanning position is at the top of the tube target. During flyback, however, the vertical position of the electron beam is shifted downwards; it therefore destroys any signal charge that has been

collected in that region of the target. Figure 8b shows the scanning positions produced a little later in the same television field; both the normal and flyback portions of the line scan have moved down the target area. A little later on in the field interval, the situation is shown in Figure 8c.

Two points are important in this latter case. The first is that the flyback portion of the line scan is now shifted above the normal portion rather than below; this is so that the flyback portion always scans the same total area of the target as the normal portion; and not a rectangular area vertically displaced from that of the normal portion. The second is that the normal portion of the line scan is now reading out the charge collected at the region that was discharged by the flyback portion in Figure 8a. Thus only charge collected in the period between Figure 8a and Figure 8c will be read out by the normal scan. If this period is made to be equal to the desired shutter duration, then electronic shuttering is achieved. For completeness, Figure 8d shows the position of the normal and flyback portions of the line scan at the end of the television field period.

Figure 9 shows the waveform that must be applied to the field deflection circuitry in the camera tube in order to achieve this scanning action. The period in the figure is the effective period of the electronic shutter. Each interval for an active line portion of the line scanning period is interleaved with a line flyback interval.

If the exposure period differs from exact integral

numbers of half-cycles of the mains frequency (due perhaps to mains frequency fluctuations) it appears likely that some worthwhile degree of flicker suppression will still be obtained.

CLAIMS

1. A video camera comprising optical-to-electronic transducer means for viewing an illuminated scene and producing an electrical signal representative of the scene in scanned form having a defined scan rate, and means for restricting the effective exposure time of the transducer means such that the exposure time is related to the period of the frequency of the variation in ambient scene light during each scan of the transducer.

2. A video camera as claimed in claim 1, wherein the exposure time is an integral number (preferably one) of half-periods of the frequency of the variation in ambient scene light.

3. A video camera as claimed in claim 1 or 2, wherein a shutter device is located in the path of light from the scene to a photosensitive element of the camera to restrict the time any part of the photosensitive element is exposed to scene light.

4. A video camera as claimed in claim 3, wherein the shutter is a rotatable disc having segments removed therefrom to define light passing apertures and light blocking blades.

5. A shutter for a video camera substantially as described herein with reference to the accompanying drawings.

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